SPEND, SAVE AND SPLURGE – THE REBOUND EFFECT OF ENERGY EFFICIENCY INITIATIVES

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ABSTRACT

Energy Efficiency (EE) and Demand Side Management (DSM) programs are being implemented throughout the world's energy sectors, with the intention of managing the demand for energy services, improving energy security and reducing the externalities of electricity production. However, the *rebound effect* has meant that the actual savings in energy demand are often less than expected making these costly programs ineffective, or worse raising consumption. In this paper, we define the rebound effect of EE and DSM initiatives in the electricity sector, summarise the literature, and provide the foundation for investigating the extent and causes of rebound in the South African residential sector.

1. INTRODUCTION

Having surveyed the literature, spoken to numerous stakeholders, and engaged with a substantial amount of anecdotal evidence, it is clear that the notion of rebound is beyond the simple data collection exercise one would have originally expected. The purpose of this paper is to define the rebound effect, raise awareness of its importance in the field of energy policy and planning, and discuss the various challenges of quantifying and mitigating an effect that is somewhat difficult to pin down. We proceed by giving the basic definition of rebound, as gleaned from the available literature, and report on the conclusions of numerous studies and reviews on the subject. What is clear from the evidence is that the consequences of rebound can definitely *not* be ignored, and the implications of doing so would be significant, particularly in a developing country context.

The two questions researchers are beginning to answer are:

1 "What level of rebound can we expect from Energy Efficiency (EE) and Demand Side Management (DSM) Initiatives?"

2 "What measures can be put in place so that the maximum benefit of such measures can be achieved?"

We will concentrate on the residential sector for this discussion. To our knowledge, this is the first time a study of the rebound effect (RE) has been proposed in the South African context. Herein we generate the context and propose a methodology for quantifying the rebound, and identifying suitable methods of reducing its impact.

We propose a micro-level, in-depth, interactive and monitored study invoking qualitative and quantitative methods. In the study we will examine the behavioural response to EE and determine what factors (if any) affect this response. Examples of such factors may include demographic characteristics, the type of the intervention, and the nature of implementation (including active factors such as education and training). Obviously the cost of consuming a particular energy service will also play a role (including or excluding capital outlay).

The results will be used to suggest ways of improving the effectiveness of measures at the level of implementation, and very importantly, ensuring that the measures are acceptable (or even desirable) for the residential end-users. Quantitatively we aim to model the potential for inevitable rebound on mass roll-outs of new technologies such as Compact Fluorescent light bulbs.

1.1 BACKGROUND

EE is widely regarded as a positive initiative in households. In a recent report on SABC news responding to news of expected load shedding, Eskom was quoted as saying "Energy efficiency needed to become a way of life."

The intention of EE is to reduce the consumption of energy – thereby reducing economy-wide energy intensity and elasticity of energy growth with respect to GDP growth – and lower the costs of energy services consumed by households, making more income available for other basic needs. Ultimately, reduced consumption would also have the benefit of avoided investment in new generation capacity and also reduce the externalities associated with the procurement of that energy (for example CO_2 emissions from coal-fired power stations). However, in the majority of interventions, the actual energy savings are lower than expected due to an element of rebound/take-back when the costs of energy services decrease.

The RE may be particularly acute in developing countries – especially among poor households – that have a prevalence of unmet demand for modern energy services. Rebound can also be significant when there is a large shift in technology (for example the extraordinary leap in energy use that took place with the advent of the steam engine and the electric motor). Existing literature reports on empirical studies of rebound on a macro and (to a lesser extent) micro-level, however there is currently little evidence of the nature and extent of rebound in South Africa. It is important to raise awareness and develop indicators in this area at a time when EE and DSM are being implemented on a large scale, and in view of the recent reductions in generation capacity reserve margins.

It has become apparent that the household or energy-user attitude and behavioural response to the EE or DSM option requires careful consideration. An investigation is required into the behavioural response factors that need to be considered when implementing EE intervention measures so that the maximum sustainability objectives can be achieved (including social, environmental and economic). Very few studies of this nature have taken place within the developing country context, in spite of the importance being acknowledged. However, we aim to further the understanding of human behavioural response to initiatives such as EE and DSM and find methods of mitigating rebound through ongoing training and awareness initiatives as well as through policy interventions.

In anticipating the extent of potential rebound scenarios prior to the roll-out of technologies (e.g. Compact Fluorescent Light's (CFLs) and Solar Water Heaters (SWHs)), implementation measures can be adapted and customised to foster EE learning. Ultimately such learning may encourage self-adoption of EE practices among end-users.

The remainder of this paper is structured as follows. First we define the *rebound effect* with references to the literature. Then we narrow the discussion to energy efficiency in the residential sector, across the socio-demographic spectrum, and demonstrate how we intend to explore means for measuring and mitigating take-back in the realm of household energy efficiency interventions. To end off we propose a methodology for quantifying the rebound prior to the large-scale roll-out of DSM and other EE measures.

2. THE REBOUND EFFECT: DEFINITION

The concept of economic rebound was first suggested by Jevons in 1865 [3]. He realised that the gain in energy productivity as a result of introducing energy efficiency is not entirely met by the gains in productivity of other inputs, thus offsetting the gains resulting from energy efficiency. The RE is also referred to as the Khazzoom-Brookes Postulate and, sometimes, as the "take-back" or "snap-back" effect – although we shall see that "take-back" is only one element of the rebound. Pure rebound is the inherent tendency to consume more of a commodity when it becomes cheaper, such that the reduction in demand is lower than the technical savings resulting from the efficiency mechanism. Colloquially, the process can be thought of as a "spend, save and splurge" mentality. According to [2] there are two to three effects of a price reduction, namely own effect (the consumption of the good itself), indirect effect (on other commodities) and third order effect (macro level/economy-wide).

The RE can also be defined in relation to time frames (e.g. short, medium and long term) as well as system boundaries (household, firm, sector, national economy).

Simply stated, the rebound is a behavioural tendency to consume more energy due to the lower cost of energy services derived from an energy efficiency improvement [4] i.e. some, all or more of the expected energy savings were "lost" as the savings are offset by increased consumption through either longer hours of use or meeting needs for additional energy services. This can be calculated as:

$$\text{Rebound effect} = \frac{\text{expected savings} - \text{actual savings}}{\text{expected savings}}$$

A RE of 0% assumes that the expected (engineering-technical) savings were achieved through reduced consumption, whilst 100% means that no energy savings were realized and that the energy efficiency program failed. When consumption increases to the extent that the rebound exceeds 100% it is referred to as the "backfire effect". Historical examples of backfire are the reaction to the steam engine and electric motor. Empirical macro and micro-economic studies have shown that rebound is generally somewhere between 0% and 100% [2,4,6,7,8]. It is also possible to have a negative RE, such that the energy savings are greater than originally anticipated, for behavioural or technical reasons, or both. An example of the latter would be when energy efficiency is implemented alongside an energy efficiency educational campaign and the resultant savings are greater than anticipated. The different scenarios for rebound are illustrated in Figure 1.

There appears to be general agreement that the RE is closely linked to price elasticity, and also to the elasticity of substitution [2]. If a high price elasticity of an energy service is observed, a high RE can be expected. This is an important consideration in relation to policy instruments that aim to reduce energy use through measures like carbon taxes where the existence of a high price elasticity and therefore high RE will have the effect of limiting the potential energy savings of a particular policy measure.

3. RATIONALE

Generally, REs have been neglected when assessing the impact of EE, despite being of sufficient importance to merit explicit treatment. Consequently, knowledge of the size of the rebound is necessary to assess the realistic contribution of energy efficiency [5].

Ideally, an integrated approach to energy conservation and reducing greenhouse gas emissions is favourable, and both have been amply considered in the literature as sound reasons for exploring the RE. However, the two are related, and not in a linear fashion as might have been expected. To simplify the content of this review, we will therefore restrict our referral to rebound to the context of EE which in no way implies that this is more or less important motivation than climate change mitigation. For the ease of discussion we will assume that achieving maximum EE also satisfies the goal of greenhouse gas reduction (both direct and indirect consequences).

The rationale for studying the RE is to understand the underlying causal factors. Consequently, this understanding contributes to improving energy efficiency, which, in turn, is necessary for meeting the government's objectives of social, environmental and economic sustainability (from [9] 2005 discussing the DME's 2004 objectives and looking at the Energy Efficiency Scenario for South Africa). To summarise, the rationale for studying rebound integrates four themes:

- fulfilling sustainability objectives
- understand attitudes and behaviours
- energy conservation
- greenhouse gas mitigation

4. PROPOSED METHODOLOGY

4.1 PREVIOUS STUDIES

On the whole, data collection and end-use metering intended for measuring rebound are lacking. However, for meaningful characterisation of residential fuel demand, the key variables to consider are income, non-energy expenditure, household demographics, capital-cost of appliances, opportunity costs of capital and length of holding and efficiencies of the fuel-using devices. Variability may arise due to the type and availability of devices used for a particular energy service and levels of consumer awareness. Empirical validation of the baseline is crucial for producing a meaningful measure of the RE. (All points reported in [8]).

There are a number of examples indicating that the RE may be higher in developing countries due to the high elasticity of demand [10, 11]. A study in a country such as South Africa, which operates according to a dual economy, will have to consider both tiers of the (dual) economy when analysing the RE on both macro- and micro-levels.

4.2 RESEARCH QUESTIONS

The key questions we will endeavour to answer are:

What level of rebound can we expect from Energy Efficiency in the Residential Sector? What is the behavioural response likely to be on large-scale roll-outs? How can we mitigate unwanted rebound?

One of the reported difficulties of DSM is that the programs may not be able to simultaneously satisfy all stakeholders (utility company and customer) objectives [1] and the behavioural response to the initiatives is difficult to anticipate. Sustainability of any initiative is a key factor to consider prior to any roll-out, and customers should be consulted more rigorously when deciding on the appropriateness of particular initiatives.

Having defined rebound, our study now aims to uncover the impact a number of factors:

(a) Technologies/types of intervention

An example study [1] demonstrated CFLs were met with negative interest in the Western Cape (around 50% "not happy" with the quality of the light, contrasting sharply with an 80% satisfaction rate in a Mexican survey on a campaign in that country. The results of the Western Cape study (though only a small sample, reveals that the potential for reversion to incandescent bulbs may be large on a national scale as a result of dissatisfaction with performance – without having included the increasing consumptions as resulting from the cheaper lighting service. Moreover, the high cost of replacing CFLs with the same, means that there is a cost barrier resulting in reversion to incandescent bulbs. Anecdotal evidence also suggests that middle to high income households are also not satisfied with the quality of light provided by CFLs [1].

We wish to explore the potential rebound in an imminent large-scale role-out of SWHs as the potential benefits of such a program are great and the success dependent on prior understanding of the expected behavioural response.

Other measures include SWHs, geyser blankets, ripple and other remote control of hot water geysers, timer switches on geysers, efficient appliances, timer switches on lights and boilers, substitution of energy carriers e.g. LP Gas stove exchange program (met with limited success [1]).

Among the most important influences are consumer awareness and socio-cultural factors so we will investigate the impact of general awareness campaigns and energy conservation drives (public relations, Power Alert, school programs, etc).

(b) Method of roll-out (financial considerations)

The mechanism by which EE and DSM are implemented may play a vital role in response of consumers. Examples are:

- The effect of required capital outlay e.g. free handouts or exchanges of CFLs are more likely to be taken up than voluntary investment, though free hand-outs are not without their own problems (as reported anecdotally by those involved in the Measurement and Verification of CFL roll-outs).
- The impact of subsidies/incentives (e.g. for SWHs), compulsory and legally enforced restrictions, price signals and building regulations.
- The Eskom Power Alert – due to the wide exposure through television, the Power Alert campaign is said to have had a successful rate of penetration, however the actual savings are hard to quantify without a rigorous baseline and follow-up study [1]. Leaflets, training and school projects may be met with varying degrees of success.

(c) Other factors

Income, tradition and culture, perception of technology (inferior to the old) and community norms may play a role. Product satisfaction (aesthetics, price, quality of energy service and social norms) will also be a noteworthy factor.

The time over which rebound emerges must also be considered; effects may be short, medium, or long-term in nature.

In the above three points we will also have to consider the relationship of various factors to the type of rebound i.e. direct splurge, indirect splurge, substitution and absence of alternatives.

4.3 FOCUS GROUPS

The ERC is proposing a participatory needs assessment (PNA) within the residential sector. Since people are at the core of the development process, development interventions need to be driven by the needs of the people that the project intends to serve. The PNA is grounded in people-centred development and the engagement will be through appreciative inquiry. On the ground, this equates to facilitated focus group interviews, in-depth interviews with other stakeholders, and a survey consumer survey. Appreciative Inquiry methods are favoured because they encourage involvement and active engagement of the people involved. Such an approach empowers people by demonstrating respect for their views and existing capacities. In addition to the focus-groups we envisage a monitored (including load measurements) study that allows comparison between pre and post-intervention scenarios over time-frames that are consecutive and temporally similar.

4.4 EXPERIMENTAL DESIGN

From a modelling perspective the methodology for obtaining a quantitative view of the size of the RE will be to have a control group and an experimental group, each group divided into 3 socio-demographic groups (qualitative insights will also be drawn from this data). An illustration of the proposed approach is given in Figure 2.

5. CONCLUSION

In this paper we have demonstrated that the rebound effect is a complex topic. It is also one that cannot be ignored. What we know about rebound is that it exists and it has been studied at length on a macro-level but not at a micro-level. The literature indicates that it is hard to define, measure and quantify, and is likely to be vary significantly between developed and developing countries. We propose – and have already commenced – a two-year study that will involve stakeholder interactions, a pilot study and focus groups for a pre and post-intervention study. Quantitatively we will invoke experimental design methods on data obtained from measurement and monitoring, and will contribute to the understanding of response to energy efficiency and demand-side management on a national level.

5.1 REFERENCES

[1] Jevons,W.S: "The Coal Question, An Inquiry Concerning the Progress of the Nation, and the Probably Exhaustion of our Coal Mines", Macmillan, London (1865).

[2] Jaccard, M & Bataille, C: "Estimating future elasticities for the rebound effect." *Energy policy*, 2000, 28: 451-55.

[3] Berkhout, P.H.G, Muskens, J.C & Velthuijsen, J.W: "Defining the rebound effect." *Energy Policy*, 2000, 28: 425-32

[4] Laitner, J.A.S: "Energy efficiency: rebounding to a sound analytical perspective." *Energy policy*, 2000, 28: 471-75.

[5] Saunders, H.D: "A view from the macro side: rebound, backfire and Khazzoom-Brookes.", 2000, *Energy policy*, 28: 439-49.

[6] Greening, L.A, Greene, D.L & Difiglio, C: "Energy efficiency and consumption-the rebound effect – a survey.", 2000, *Energy policy*, 28: 389-401.

[7] Sorrel, S: "The rebound effect: an assessment of the evidence for country-wide energy savings from improved energy efficiency." 2007 Sussex Energy Group for the UK Energy Research Centre.

[8] Munasinghe. M: "Making Development More Sustainable: Sustainomics Framework and Practical Applications", 2007, *MIND Press* – Student Edition.

[9] Howells, M, House, J & Laitner, J: Beyond the baseline. Large-scale climate friendly development.", 2005, Energy Research Centre, University of Cape Town.

[10] Roy, J: "The rebound effect: some empirical evidence from India." *Energy Policy*, 2000 28 433-38.

[11] Jin S.H: "The effectiveness of energy efficiency improvement in a developing country: rebound effect of residential electricity use in South Korea." *Energy Policy*, 2007, 35: 5622-29.

[12] Madangombe, T.T: "Evaluation of Demand Side Management in the Western Cape" *BSc Fourth-year Thesis*, Department of Electrical Engineering, University of Cape Town, 2006

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Presenter:
The paper is presented by Stephen Davis.

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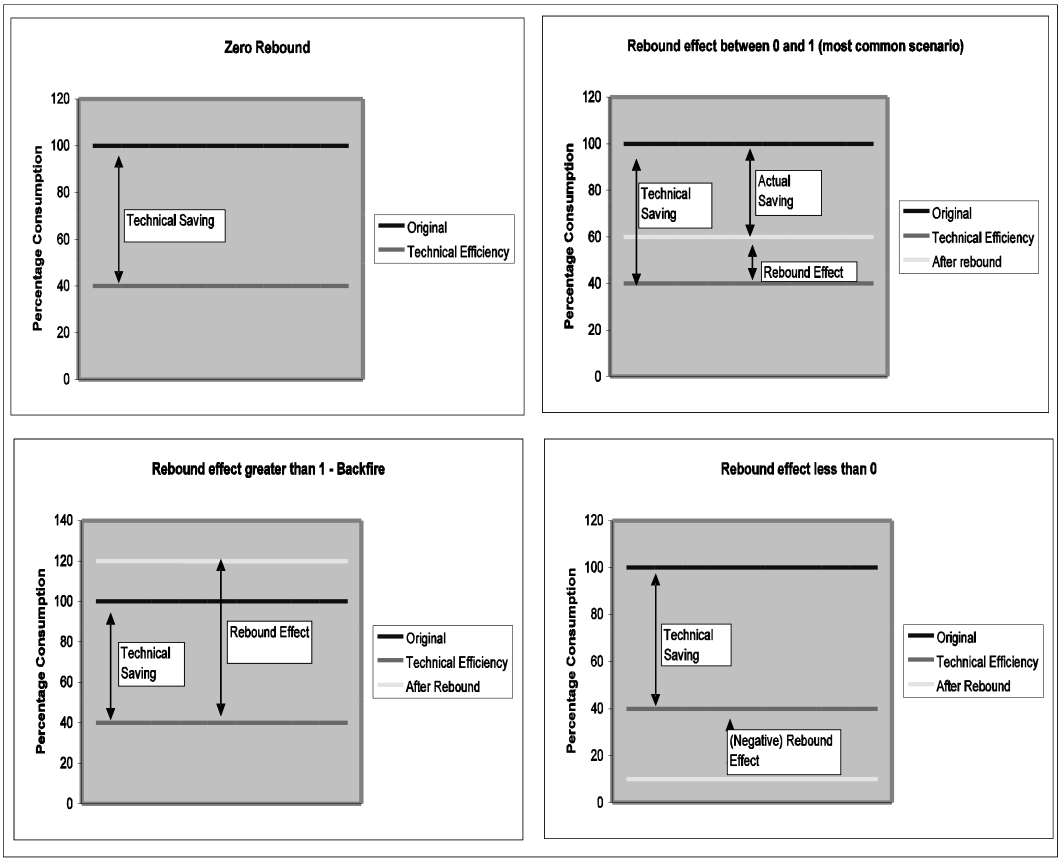

Figure 1: Rebound Scenarios

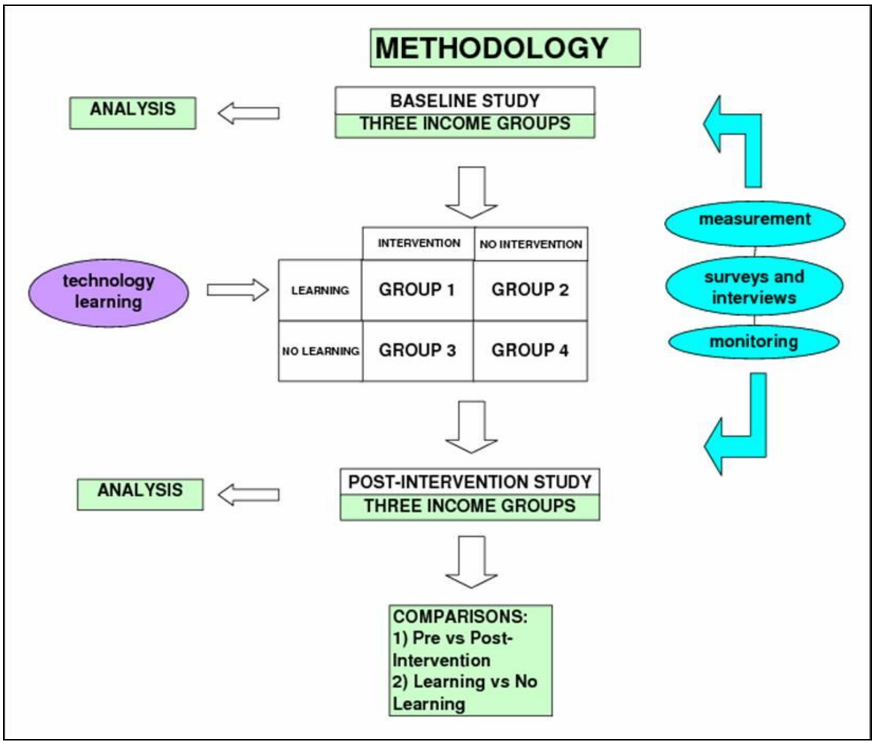

Figure 2: Proposed Methodology